Abstract

Transport is considered the primary contributor to global carbon emissions. Recently, emerging countries were experiencing increasing urbanization, leading to significant concerns regarding carbon emissions, energy security, and traffic congestion, driven by the increased demand for transit and the rising number of vehicles. The acceleration in urbanization and passenger demand significantly elevates the demand for sustainable transport solutions. This is due to urban transportation's impact on public health, as well as its influence on the economic, environmental, and energy efficiency aspects of emerging nations. Public transportation is regarded as the foundation of sustainable transportation globally. This is due to its ability to provide a more economical, reliable, and environmentally friendly option compared to other modes of transportation, such as private motor vehicles. The rise in public transport use will contribute to a decrease in private vehicle usage; this further helps in the reduction of carbon emissions. To enhance the effectiveness and efficiency of transportation, more comprehensive frameworks are necessary to assist transit agencies in delivering better services, thereby attracting more commuters to public transportation and reducing the reliance on private and diesel vehicles.

Generally, the planning process of the bus transport is segmented into three stages: strategic, tactical, and operational planning. The strategic stage generally deals with long-term decision planning and addresses the issue of network design and resource planning; tactical stage deals with short-term planning and addresses the issue of timetabling and frequency optimization problems; and finally, operational stage deals with daily planning decisions and generally addresses the problem of improving the operational efficiency and effectiveness of the available resources by optimizing their assignment to fulfil the daily demand of passengers. But still, many transit agencies in developing countries have limited resources to perform this planning process efficiently and rely on manual planning processes. Failure to perform this planning stage can result in a suboptimal distribution of resources such as buses, drivers, and chargers.

Operational planning is the main stage where available resources are utilized to cater to the demands of the network and generally focus on two main problems of bus and driver

scheduling. Further, many transit agencies globally are introducing the electric buses in the network, which makes the scheduling process more complex because of limited capacity of the batteries, frequent requirement and long duration for charging activity. And to achieve better financial and operational efficiencies, generating the optimal bus, driver, and charging schedule is a very essential part of operational planning. The traditional method of bus planning is not able to address the electric bus operational problems that include finding out the minimum replacement ratio, and optimize bus schedule, charging schedule, charging infrastructure, and driver schedule for electric buses. So, to address all these issues, the thesis provides the solution for different problems of operational planning simultaneously. First, a constraint programming model is developed to assist transit agencies in minimizing the replacement ratio, thereby reducing the need for additional buses. But, due to the complexity of the exact method, the generation of a solution for a large instance is difficult. Subsequently, a heuristic algorithm was used that solved the problem in a very short time while generating the optimal schedule for electric buses.

The second section of the electric bus scheduling addresses the issue of optimizing the bus's and charging schedule, permitting charging at the terminal with the opportunity charging option available at both the depot and the terminal. A optimization model is initially employed to address the electric bus scheduling problem, aiming to minimize the cost of electric buses. Subsequently, an optimization algorithm is utilized to determine the requisite number of chargers at both the depot and terminal, sequentially based charging demand generate during the electric bus scheduling. The results indicate that substantial cost savings can be achieved by permitting terminal charging in conjunction with opportunity charging options.

Furthermore, this thesis develops an integrated model to simultaneously address the electric bus scheduling, charging scheduling, and charging infrastructure problem, with the objective of minimizing both the cost of vehicle and the chargers. Furthermore, an integrated optimization algorithm is utilized to generate the solution for large instances. To assess the efficiency of the developed methodology, the integrated model and algorithms are tested on a realistic scenario from Bangalore, India. The results demonstrate the efficiency of generating the optimal bus schedule and charging schedule, as well as identifying the optimal location for the charging station within the transit

network, all within a very short time frame. The results show that solving this problem integrally leverages the interdependencies among the various issues, resulting in better outcomes compared to solving them sequentially. Additionally, to evaluate the impact of four parameters such as the operational time, maximum range, minimum charging time, and the number of chargers permitted at the terminal on the required bus fleet and chargers, a sensitivity analysis has been conducted.

Finally, this thesis presents another integrated methodology for addressing the scheduling problem of electric bus drivers while optimizing the charging schedule and infrastructure. First, it provides an integrated optimization model that optimize the costs associated with electric buses, chargers, and drivers, including overtime costs incurred by the drivers. But due to the complexity of the model, it is unable to generate the optimal solution in the specified time limit. Subsequently, an optimization algorithm is provided that is able to generate the best solution in a very short time and produce the best results for the electric bus schedule, charging schedule, and driver schedule. Furthermore, this thesis examines the impact of parameters such as operational time, break time, and minimum time limits for providing breaks to drivers on the number of buses, drivers, overtime trips, and the overtime worked by drivers.

Keywords: *Optimization, Public Transport*, *Electric Bus Scheduling, Charging Infrastructure Planning, Charging Scheduling*, *Driver Scheduling, Overtime Trips.*